# :- Assignment 1 Solution :-

1) Based on the size, weight and Mode of operation one can classified the Unmaned Aircraft.

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2) Endurance of the Unmanned Aircraft depends upon -

i) Payload ii) Aerodynamics of UAV iii) Atmospheric conditions

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3) from the hydrostatic equation the variation of pressure, temperature and density with altitude are drived without considering the variation of acceleration due to gravity with altitude.

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4) Given altitude $h = 17\,km$

$$\rho_{17} = ?$$

Step i) first we have to find the density at 11 km. $\quad | \; \lambda = -6.5\,K/km$

using
$$\frac{\rho_{11}}{\rho_{sea}} = \left(\frac{T_{11}}{T_{sea}}\right)^{-\left[\frac{g}{R\lambda}+1\right]}$$

$$= \left(\frac{T_{sea} + \lambda \times h_{11}}{T_{sea}}\right)^{+\left[\frac{g}{R\lambda}+1\right]}$$

$$= \left(\frac{288.16 - 6.5 \times 11}{288.16}\right)^{+\left[-\frac{9.81 \times 1000}{6.5 \times 287}+1\right]}$$

$$= \left(0.75187\right)^{4.25864}$$

$$\frac{\rho_{11}}{\rho_{sea}} = 0.29685$$

$$\rho_{11} = 0.29685 \times 1.2256$$

$$\boxed{\rho_{11} = 0.36382\ kg/m^3}$$

for 17 km

$$\frac{\rho_{17}}{\rho_{11}} = e^{-\frac{g}{RT_{11}}[h_{17}-h_{11}]}$$

$$= e^{-\frac{9.81}{287\times216.66}[17-11]\times10^3}$$

$$\frac{\rho_{17}}{0.36382} = 0.38863858$$

$$\boxed{\rho_{17} = 0.141394 \ kg/m^3}$$

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(5) Given UAV flying at altitude = 15 km

Total pressure measured by pitot tube ⇒ $P_0 = 0.11376772 \ N/m^2$

True speed $(V_T) = ?$

First we have to find the static pressure at 15 km followed by 11 km.

$$\frac{P_{11}}{P_{sea}} = \left(\frac{T_{11}}{T_{sea}}\right)^{-\left[\frac{g}{\lambda R}\right]}$$

$$= \left(\frac{216.66}{288.16}\right)^{5.25864}$$

$$\frac{P_{11}}{P_{sea}} = 0.223198$$

$$P_{11} = 1.01325\times10^5 \times 0.223198$$

$$[P_{11} = 0.2261556\times10^5 \ N/m^2]$$

$$\frac{P_{15}}{P_{11}} = e^{-\frac{g}{RT_{11}}[h_{15}-h_{11}]}$$

$$= e^{-0.63105}$$

$\frac{p_{15}}{p_{11}} = 0.532029$ $\therefore P_{15} = 0.12032 \times 10^5 \ N/m^2$

→ density at 15 km ⟹ $\frac{\rho_{11}}{\rho_{sea}} = \left(\frac{T_1}{T_{sea}}\right)^{-\left[\frac{g}{\lambda R}+1\right]}$

$\therefore = (0.75187)^{4.25864}$

$$\boxed{\therefore \rho_{11} = 0.36382 \ kg/m^3}$$

Now using,

$$\frac{\rho_{15}}{\rho_{11}} = \frac{P_{15}}{P_{11}}$$

$$\boxed{\therefore \rho_{15} = 0.1935 \ kg/m^3}$$

using, $P_0 = P + \frac{1}{2}\rho v^2$

$$(P_0)_{15} = P_{15} + \frac{1}{2}\rho_{15}(V_s)^2$$

$$\therefore V_T = \sqrt{\frac{2(P_0 - P)_{15}}{\rho_{15}}}$$

$$\therefore V_T = \sqrt{\frac{2(0.1376772 \times 10^5 - 0.12032 \times 10^5)}{0.1935}}$$

$\therefore \underset{\sim\sim\sim\sim\sim}{V_T = 133.94 \ m/s}$ → Nearest answer is 74.165 m/s

Ex-6 Temperature at 17 km and 13 km will be same. which is 216.66

$$\therefore \frac{T_{17}}{T_{13}} = \frac{216.66}{216.66} = 1$$

(7) the density ratio at 20 km and 11 km ⇒ ?

we know from Question No. 4

$$\left[ \rho_{11} = 0.36382 \ kg/m^3 \right]$$

⇒ density at 20 km can be found using -

$$\frac{\rho_{20}}{\rho_{11}} = e^{-\frac{g}{RT_{11}}\left[ h_{20} - h_{11} \right]}$$

$$= e^{-\frac{9.81}{287 \times 216.66}\left[ 20-11 \right] \times 10^3}$$

$$\boxed{\frac{\rho_{20}}{\rho_{11}} = 0.2417}$$

→ Nearest answer is → 0.259

~~$\rho_{20}/1$ 0.084267~~

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(8) The pressure ratio at 20 km and 10 km ⇒ ?

pressure at 10 km can be found using

$$\frac{P_{10}}{P_{sea}} = \left( \frac{T_{10}}{T_{sea}} \right)^{-\left[ \frac{g}{\alpha R} \right]}$$

$$= \left( \frac{223.16}{288.16} \right)^{5.25864}$$

$$\frac{P_{10}}{P_{sea}} = 0.2607$$

$$\boxed{P_{10} = 0.264189 \times 10^5 \ N/m^2}$$

for 20 km

$$\frac{P_{20}}{P_{11}} = \frac{\rho_{20}}{\rho_{11}}$$

from question 7

$$P_{20} = \frac{\rho_{20}}{\rho_{11}} \times P_{11}$$

from question - 5

$$= 0.259092 \times 0.2268556 \times 10^5$$

$$\left[ P_{20} = 0.058595 \times 10^5 \right] N/m^2$$

so $\Rightarrow$ $$\frac{P_{20}}{P_{10}} = \frac{0.058595 \times 10^5}{0.264189 \times 10^5}$$

$$\boxed{\frac{P_{20}}{P_{10}} = 0.22179}$$

(9) from Question (5) (see the solution of Question 5)

the pressure at 15 km -

$$P_{15} = 0.131839 \times 10^5 \ N/m^2$$

$$\boxed{P_{15} = 0.131839 \times 10^5 \ N/m^2}$$

(10) Given - $$\frac{h_G - h}{h} = 1\%$$

using $$h = \frac{h_G R}{R + h_G}$$

where $\Rightarrow$

$h_G \Rightarrow$ Geometric altitude

$h \Rightarrow$ Geopotential altitude

$R = 6378.14$ (Radius of earth)

$$\Rightarrow h R + h_G h = h_G R$$

$$h_G h = h_G R - h R$$

$$\frac{h_G}{R} = \frac{h_G - h}{h}$$

$$\frac{h_G}{R} = 0.01$$

$$h_G = 0.01 R$$

$$h_G = 0.01 \times 6378.14$$

$$\boxed{h_G = 63.7814 \text{ km}}$$